Fall 2005

Swoosh and Boom

QUARTERLY

Indian Head Division

N S W C

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Cover: A Tomahawk Attack Missile (TLAM) is launched from the guided missile destroyer USS Winston S. Churchill. Winston S. Churchill was operating in the eastern Mediterranean Sea conducting missions in support of Operation Iraqi Freedom (see article page 14). U.S. Navy photo by Chief Fire Controlman James Krogman.

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Indian Head Division
Naval Surface Warfare Center
"DOD Energetics Center"

Captain Joseph N. Giaquinto
Commander
Indian Head Division, NSWC

As we enter into fiscal year 2006, the Warfare Center Divisions continue to face an increasingly challenging environment. In FY05, Indian Head Division (IHDIV) met all of its financial goals and mission requirements, while implementing tens of millions of dollars in cost reductions and rightsizing the work force. We have also refocused our vision and realigned our organization to meet the objectives of Warfare Center alignment and our redefined role as a DoD Energetics Center.

Over the last several months, leadership positions across the Navy have changed hands, including ADM Michael G. Mullen, our new Chief of Naval Operations, and VADM Paul Sullivan, Commander, Naval Sea Systems Command. These new leaders are calling for the Navy to take a "fresh look" at sea power to better meet the challenges of the 21st century. ADM Mullen has stressed that the time has come for the Navy to look at sea power as a team effort, focusing on cooperative partnerships that operate routinely with one another.

In response to this request, VADM Sullivan delivered specific direction that will fine-tune the organization through an agile, aligned, and action-oriented Warfare Enterprise. He is calling for NAVSEA's evolvement into an organization that emphasizes best practice and sharing across the Command to include warfighting capability requirements and organizational alignment.

The continued transformation of NAVSEA, coupled with the recent confirmed recommendations of the 2005 Base Realignment and Closure (BRAC) process, creates opportunity and challenges for IHDIV. In response, IHDIV has organizationally realigned around key energetic competencies, enabling the organization to proactively respond to emerging requirements and future technology thrusts. Focusing on the continuum of the energetic system engineering, we will be better aligned to "push" technology from the research, development, test and evaluation areas, and "pull" technology via the systems engineering components. Our philosophy for alignment capitalizes on IHDIV as a critical and premier player in the security of our nation.

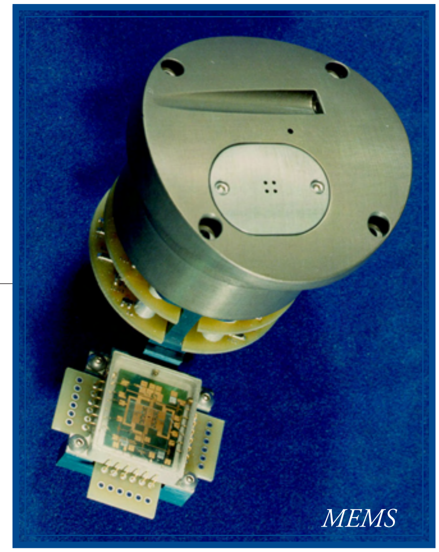
In addition, the BRAC process officially designated Indian Head Division as an Energetics Center. By this recognition, Representative Steny Hoyer (D-MD) noted, "that's a big 'E' and a big 'C'… this is the most capable Energetics Center in the country … you have an opportunity to enhance Indian Head Division's mission more now than you have in the past…". IHDIV remains the national leader in full-spectrum energetic system engineering. It is imperative that we continue to fulfill our obligation as a big "E" and big "C" premier technology provider, bringing our nation the very best the Energetics competency has to offer.

This Fall Edition of the *Swoosh and Boom* is a testament to our talented workforce and their dedication in providing the soundest technical solutions, and the safest and most reliable weapons and weapon systems to our fighting forces. You will read about digital technology that yields important benefits for the warfighter in the areas of safety, quality, and efficiency; reactive targets - a high-tech training aid to assist Special Forces; propellant lasers - a unique capability to evaluate the performance of energetic material; the production of POU-2 casting powder - a critical component in the Navy's underwater launch systems; and the sustainability of energetic systems support to ensure warfighter needs are met.

I continue to take pride in leading an organization that provides such unique and exceptional technologies that are critical to the defense and security of this nation. The accomplishments in this edition of the *Swoosh and Boom* are not only a reflection of the hard work and dedication of the men and women of the IHDIV, but of their tenacity to withstand change and capitalize on opportunity.


Standard Missile


SMAW-NE


MEMS

We ensure operational readiness of the United States and allied forces by providing technical capabilities necessary to rapidly move any "energetics" product from concept through production, to operational deployment. Our capabilities include: research, development, testing, and engineering; acquisition; manufacturing technology; manufacturing; industrial base, fleet, and operational support for warheads; explosives; propellants; pyrotechnics; energetic chemicals; rocket, missile, and gun propulsion systems; missile simulators, trainers, and test and diagnostic equipment; tri-service cartridge-actuated devices, propellant-actuated devices, and aircrew escape propulsion systems; and other ordnance products.

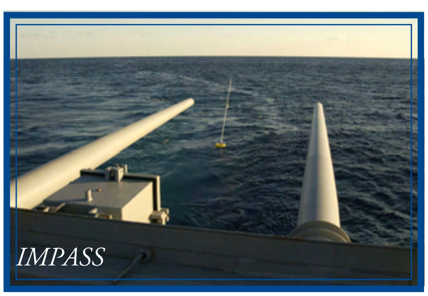
Our capabilities provide technical expertise for special weapons, explosive safety, and ordnance environmental support. These technical capabilities and this expertise support all Naval warfare areas as well as the Army, Air Force, and private sector.


Tomahawk


Sea Sparrow


Torpedo


CAD/PAD


IMPASS


Warhead Explosion

Virtual Training Studio: Digital Practice Makes Perfect

by Allyn C. Buzzell
Courtesy of the Office of Naval Research (ONR), N STAR Program, STARLINK Newsletter

The assembly of explosive devices that actuate air crew escape systems requires highly trained operators and zero tolerance for mistakes. The lives of U.S. warfighters literally depend on the fail-safe functioning of the devices. But how do you ensure such precise manufacturing when there is turnover in the workforce or when experienced operators assemble the devices only periodically as demand requires?

The Virtual Training Studio aims to use digital technology to teach workers to assemble, disassemble, or repair devices and equipment in a virtual environment before they work on the actual items. The joint research program is sponsored by the Indian Head Division, Naval Surface Warfare Center, Indian Head, Maryland and the Center for Energetic Concepts Development (CECD) at the University of Maryland (College Park).

Jeb Brough takes a spin in the Virtual Training Studio. Photo courtesy of ONR.

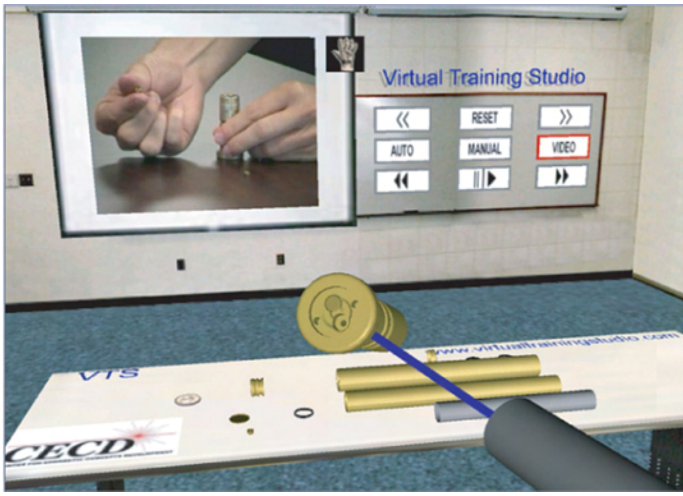
The Virtual Training Studio is the invention of a softwaredesign team led by Dr. Satyandra Gupta, associate professor of mechanical engineering at the University of Maryland. Other primary team members are Dr. Dave Anand, Director of the CECD; Jeb Brough, a former IHDIV employee who is currently a full-time graduate student at the university; and Max Schwartz, a software engineer at the CECD and former student.

The IHDIV team consists of Ralph Pettersen, Director, CAD/PAD Production; Dr. Chester F. Clark, Senior Associate in the Joint Program Office for CAD/PAD; and Cindy M. Yeager, Senior Staff Engineer, CAD/PAD Production.

According to Dr. Clark, "The Virtual Training Studio gives us the opportunity to train our employees on manufacturing processes that are done only intermittently and also to archive the processes for future training as our production workforce and engineering staff change over time."

In the Studio

Trainees interact with a tutorial using a head-mounted display and hand-held wand. Four optical trackers and two gyroscopes track the position and orientation of the trainee and the wand. The



Tutorial shows trainee a video of assembly process.

trainee manipulates the assembly parts and clicks on various response buttons using a virtual laser pointer.

Several modes of interaction are possible. In the interactive simulation mode, users can position and orient the parts of the assembly. Once the configuration is properly aligned, the user clicks on the "complete" button and watches the animated completion of the assembly.

Trainees can also visualize how the task is done by choosing the animation mode, which shows the components being assembled. Another option, the video mode, plays a video clip of an actual part being attached to the assembly. The user can watch the video and repeat, pause, rewind, and fast forward to study the various assembly tasks.

According to Dr. Gupta, such training maintains the user's proficiency and reverses memory attrition that may occur when performance of a task is sporadic. The researchers are currently enhancing the training module by adding virtual tool usage capability.

Better All the Time

Employing artificial intelligence features, the Virtual Training Studio tracks errors by individual users and responds by making adjustments or clarifications in the tutorial or by presenting a different scale or perspective on the assembly process. For example, if a user did not remember what part to assemble next (a process retention error), the assessment component instructs the tutorial to replay a short sequence of steps.

The assessment component also analyzes multiple user logs and answers to the mandatory exam to detect points in the assembly process where many users make errors, uncovering possible weaknesses in the tutorial itself. The assessment component then attempts to clarify the tutorial by adding visual aids (such as arrows) or additional text or audio instructions.

Engineers also have the ability to build new assembly protocols. Using the authoring module, the engineer loads a set of files that describe an assembly. The module then creates an animation sequence for the assembly and generates a text outline of the process, using object motion and collision detection. The engineer can edit the instructions and then incorporate them as a new tutorial in the training module. The engineer can also print them to create a paper-based manual.

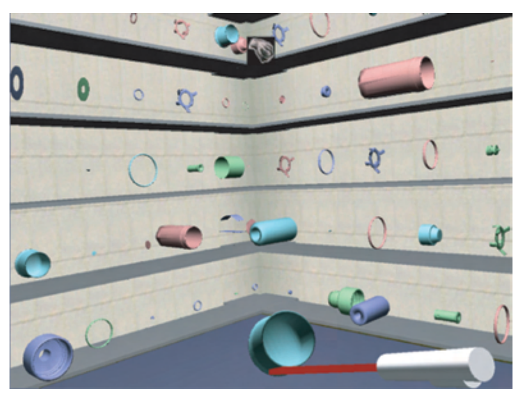
Payoffs Now and Later

The Virtual Training Studio yields important benefits in the areas of manufacturing efficiency and safety, product quality, worker proficiency, training effectiveness, and instructor productivity. Besides its near-term application at IHDIV's manufacturing facilities, other uses will evolve.

"Our immediate interest is to improve the visualization capability and memory retention of workers in a manufacturing setting," says Dr. Gupta. "However, one could imagine many natural extensions for our research."

One such potential military use might be to develop virtual training software to support equipment maintenance proficiency right on the battlefield.

Assembly components in the Virtual Training Studio. Photos courtesy of ONR.



Developing High-Tech Training Tools for Special Forces

Watch Out, It Shoots Back!

by J. Geoffrey Schubert and
Matt Kennedy
Energetics Evaluation Department

You are in the interior of a building harboring known hostiles with hostages. It is your job to enter each area undetected and immediately suppress any enemy, as your team fans out through dark hallways and rooms, recovering the captured citizens.

You come upon a closed door, and using night vision goggles, can see the slight flicker of candles brightly showing at its base. With a couple of quick hand signals, a teammate sets an entry charge on the door, while another prepares to use a concussion grenade.

Everything is set. The steady, focused breathing of the team is barely audible as a silent command is given to breach. With a flash and a bang, the door is permanently opened and a concussion grenade sails through the smoking hole.

U. S. Navy SEALs (Sea, Air, and Land), seen here receiving tactical mobility training, will benefit from the newly developed reactive target. Official U.S. Navy photo.

A few short adrenaline-pumping seconds later, an intense flash of light accompanied by two very loud cracks precedes the rapid ingress of a fully-armed and determined elite fighting force known as a United States Navy SEAL team. Seconds later, following rapidly fired bullets, two insurgents are dead and team members are taking positions around the hostages who have been knocked out from the grenade, but are otherwise unharmed. In less than a minute the team, plus eternally grateful additions, will be on their way out of the building and back to freedom.

Training scenarios for the missions just described go on every day all over the world in defense of life, liberty, and democratic ideals. Recently, a team of scientists and engineers from the Non-Destructive Evaluation (NDE) and Detonation Technology Branches of the Energetics Evaluation Department at Indian Head Division (IHDIV) were given the unique task of designing and building a new, high-tech, but tough, training aid that would increase the realism during these evolutions. Requirements of the new apparatus included the capability of shooting at the would-be rescuers as any good bad-guy would.

Representatives from Naval Special Warfare approached Program Managers in IHDIV's Customer Advocacy Office with an idea for a mobile, responsive 'target' that would greatly increase the realism of their training. The prospective customer wanted something that would act like a human in many ways, including the ability to shoot back until neutralized.

Geoffrey Schubert securing the wooden support board for the paintball guide tube to the gun box in preparation for a customer demonstration.

With this new requirement in hand, the NDE group was approached to propose a solution. Through a lot of hard research and discussion, the proposal from Robert Beagley, Matt Kennedy, and Geoffrey Schubert won the customer's support. With that, the Reactive Target project began with much excitement.

The initial team possessed a wide range of talents. Beagley, with an Engineering-Physics degree had the versatile talent needed for the project. Kennedy, a mechanical engineer, led in the design and fabrication of the frames, mounts, moving parts, and compressed gas harnesses. Schubert, the computer scientist, would be handling the programming of the motion controller - the 'brain' of the system. Well into the first year of the project Steve Shaner, a talented electrical engineer, noted most recently for his contributions to IHDIV's successful Functional Ground Test program for the Tomahawk cruise missile, joined the team. Together, they collaborated and brainstormed general design characteristics, behavior, and the mechanical and electrical solutions to obtain the desired outcome.

Named the Reactive Target system, this novel solution brings together commonly available components, including a clothed manequin, paintball gun, and various electronic sensors and mechanisms. Setup for the system is easy and consists of simply placing the clothed dummy on the provided stand, turning on the power, opening the air valve, cocking the gun and leaving the room. When the participants are ready, the 'activate' button on the remote control is pressed by the Range Safety Officer. Once activated, the system 'looks' for intruders with sensors, exactly the kind you would use for home or building security. If movement is spotted, the dummy and paintball gun are quickly rotated to the general direction of the intruder and will fire paintballs until the dummy is shot off its base by the trainee or until another sensor detects movement and the system rotates to face the new threat.

Additional features specifically requested by the customer included the ability of the system to be temporarily 'disoriented' by detecting the loud pop of a so-called 'flash-bang' or 'flash-crash' grenade. Similar devices are also used by law enforcement units to knock out everyone in a small area, allowing the criminals to be apprehended (or shot), while not injuring hostages or receiving return fire. The ideal scenario is that the system never fires one paintball because it will have been disoriented by the grenade and the 'dummy' shot before it could 'wake-up' and fire back.

The second added feature is one that greatly impressed the SEALs upon the first demo in April of this year. Not only can the system fire its paintballs at a slow base rate, with a simple press of a button it can also change over to what is called 'spray and pray' mode. So named for the imagined evildoers knowing there is no room for escape, spraying bullets at their attackers while simultaneously praying to live through the situation. It was a great pleasure to see SEAL trainees with their fingers itching on the triggers of their M-16s when the sound of the fully-automatic 14 round-per-second 'spray-and-pray' mode was activated.

Now you may be thinking you might not want to be the person resetting this machine, as you would expect to get pounded with bright pink paint (yes, pink was chosen on purpose) as soon as you put the dummy back on the base - not so! The Reactive Target system has one more clever feature in its wireless remote control. This device allows the operator setting up the unit to safely exit the room before fully activating the system. It will also allow the user to verify

The initial IHDIV team with the Reactive Target. L to r, Robert Beagley, Matt Kennedy, and J. Geoffrey Schubert.

that the system is inactive before entering again to reset for the next run. To minimize additional risks associated with using an electrical, compressed air, and partially metal system in a live-fire arena, many safety features were incorporated in the systems design. Electrical issues are resolved by using internal absorbed glass mat (AGM) batteries. This ensures no external cables to trip on, shoot up, or hinder the setup or movement of the system. The AGM-style batteries also have the benefit of deep-cycle operation and will not leak battery acid even if shot.

The risks of using compressed air and metal framing within a live fire environment are minimized by extensive use of Armortex™ bullet-resistant woven fiberglass panels from Safeguard Security Systems. These panels can stop most non-armor-piercing rounds up to 0.45 caliber, even multiple times at the same location. The panels are mounted so as to protect the inner workings and minimize any possibility of ricochet.

The design mandates extensive use of various components which results in ease of maintenance and repair. Also included are spare parts kits with extra pre-cut-to-size Armortex™ panels, nylon screws to hold them on to the frame, paintball marker barrel cleaners, extra paintballs, a battery charging unit, and additional sensors (since they are outside the protective paneling and could easily get shot).

The scenario described earlier is the primary one the customer expects to run. The Reactive Target is positioned in a room or hallway and must be 'killed' by the team as they scour the building looking to eliminate threats and rescue hostages. The target can also be placed in almost any other situation where the trainers need something that looks and acts far more human than most of their previous generation targets on the range.

The older conventional targets are typically flat boards with a face image and an electrified grid that, when shot, causes the plate to fall over. They cannot be dressed up, do not look realistic and do not shoot back.

As with any new system design, future improvements are anticipated to the Reactive Target system in order to increase its effectiveness and functionality. Other possible uses for a Reactive Target include non-hostage-rescue combat training by various military branches, FBI agent training, and local law enforcement training centers. As this article goes to print, the first reactive target is being prepared for delivery.

The Reactive Target project is just one more way IHDIV's talented team is contributing to our nation's security and defense. If you would like additional information on this project, or the capabilities of the NDE Branch, contact J. Geoffrey Schubert, john.schubert@navy.mil. For additional information on the capabilities of the Detonation Technologies Branch, contact Robert Beagley, robert.beagley@navy.mil.

"Focusing" on the Propellant Laser Initiation Evaluation Capability

IHDIV/NSWC Upgraded CKU-5C/A Rocket Catapult Program

by Thomas Blachowski
CAD/PAD Department

Lasers and laser energy can be utilized for a wide range of applications that include use in scanners, CD players, medical procedures, telephone communications, and, in the distant future, may include development of light sabers to allow the Jedi Knights to do battle with the Republic and Darth Vader.

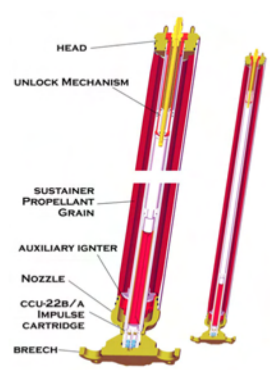
Laser Energy provides unique capability to evaluate the performance of various energetic material. HeNe laser shown.

However, in this age, engineers continue to develop new uses for lasers and laser energy. This has become a high priority for the commercial sector and for military applications as well.

The CAD/PAD Department at the Indian Head Division, Naval Surface Warfare Center (IHDIV has developed the unique capability to evaluate the performance of various energetic materials utilizing a laser as the initiation source. Laser energy provides a repeatable thermal input from which the initiation characteristics of various energetic materials can be evaluated. Identifying these major energetic material characteristics allow system engineers to optimize their initiation mechanisms to meet specific operational requirements. For example, evaluating the initiation characteristics, such as required ignition stimulus and time to reach maximum pressure, of various hydroxy-terminated polybutadiene (HTPB) composite propellants allowed the CKU-5C/A designers to select the optimum composition for use in this enhanced rocket catapult.

Developing the laser initiation (or ignitability) capability at IHDIV has been an on-going process over several years. Building 481, located across from the Albert T. Camp Technical Library, has been configured to allow use of a wide variety of lasers. The IHDIV Safety Department has worked with the CAD/PAD Department personnel to formalize and approve all the necessary procedures and protocols to allow safe and reliable operation of the lasers and related equipment. Standard Operating Procedure (SOP) "CO_2 Laser Operation - Laser Ignitability Program" (P50027), in addition to periodic reviews and safety training updates, have allowed the laser team to successfully complete a significant number of laser initiation studies and evaluations.

A carbon dioxide (CO_2) CAD/PAD laser is the primary tool for the majority of laser initiation studies. Installed almost 30



The rocket catapult launches the ejection seat and crewmember from the aircraft via the telescoping tube powered by the CCU-22/B cartridge.

Rocket Catapult
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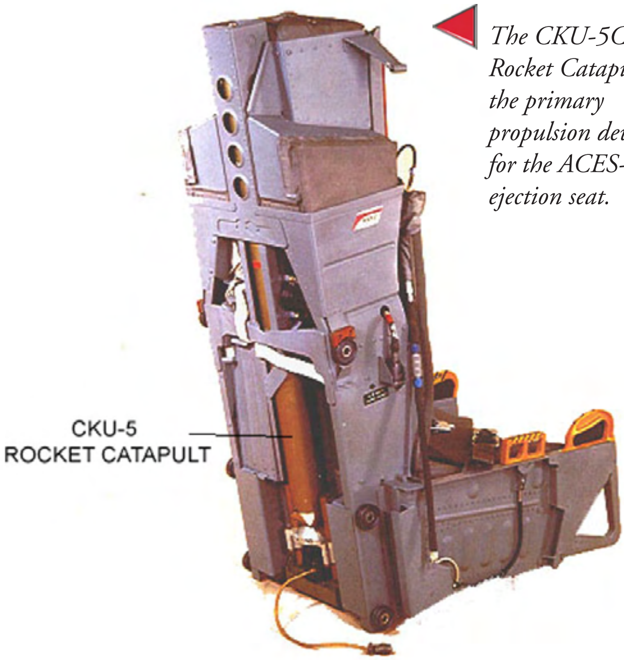


The CKU-5C/A Rocket Catapult is the primary propulsion device for the ACES-II ejection seat.

years ago, and through a series of on-going upgrades and maintenance actions, the CO_2 laser remains fully capable of providing the pulsed energy to conduct energetic material initiation evaluations and studies. Yes, equipment originally designed in the 1970s does require very specialized care and, yes, there are plans to upgrade the CO_2 laser capability; however, the current Coherent Everlase Model 400 continues to provide outstanding service.

In addition to the CO_2 laser itself, a consistent test methodology was developed. To fully characterize the initiation characteristics of the energetic material, four differing laser power levels (usually 10, 20, 30, and 40 watts respectively) are used. Twenty individual laser initiation tests are conducted at each power level. Therefore, to complete a single propellant evaluation, a total of 80 individual tests must be completed (an 80 sample test series can be completed in 2 hours). At a fixed laser power level, each individual sample is independently exposed to a pulse of a different duration (usually these pulses are less than 1 second). At the end of each pulse, the propellant sample either (a) continues to react until the sample is fully consumed which is defined as "the sample has achieved sustained combustion," or (b) the sample extinguishes or "does not achieve sustained combustion." By varying the pulse duration, the Neyer Sensitivity Analysis (a mathematical code that is widely used to efficiently determine threshold characteristics based on a limited number of tests) is used to generate the 50 percent "all fire" threshold level for that laser input power. (Note: The "all-fire" threshold level is defined as the stimulus required to initiative a device 99.9 percent reliably with a 90.0 percent confidence interval.) In addition, the time to first light (or ignition delay) is measured for each individual test. The time to first light is the point at which a photodiode records visible light being generated from the sample.

The results from these propellant evaluations and studies are used to support numerous IHDIV development programs, engineering studies, and failure investigations. Previous efforts have included an EX-98 Propellant Study, Extended Range Gun Munition (ERGM) Study, M9 - HY91 Propellant Evaluation, HYDRA-7 Propellant Ignition Study, and Metastable Intermolecular Composite (MIC) Study among others. On-going efforts include a Nulka Propellant Aging Study and a contribution to the CKU-5C/A Alternate Propellant Study.

As presented in a previous Swoosh and Boom article (Fall 2004), the CAD/PAD Department recently completed a program to change the propellant used in the CKU-5C/A Rocket Catapult and in the CCU-22/B Impulse Cartridge. The CKU-5C/A Rocket Catapult is the primary propulsion device for the ACES-II ejection seat. The rocket catapult is a two-stage combination device that first launches the ejection seat and crewmember from the aircraft cockpit via its telescoping tube (which is powered by the CCU-22/B cartridge). Subsequently, the rocket catapult then propels the seat and the crewmember through a safe trajectory to an adequate height for parachute recovery utilizing the integral rocket motor. The ACES-II ejection seat is used in the United States Air Force A-10, F-15, F-16, F-117, F-22, B-1, and B-2 aircraft. The ACES-II ejection seat has saved thousands of crewmembers lives over its 30+ years in service.

The primary objective of the CKU-5C/A Alternate Propellant program was to introduce propellants using more modern binder systems (i.e. HTPB) and to reduce the increasing producability issues associated with the previous carboxy-terminated polybutadiene (CTPB) propellants. Some of the ingredients of the previous CTPB propellants are increasingly difficult to obtain from U.S. suppliers. A complete review of this program can be found by reading the 2003 SAFE National Symposium technical paper authored by Thomas Ilkka, Ray Bazil, and Craig Wheeler all of IHDIV. For the laser initiation program, the primary objective was to determine the ignition characteristics of the varying propellant compositions considered under the larger program. In addition, the laser initiation program assisted in determining which potential composition could be capable of reducing the ignition delay of the rocket motor while ensuring reliable function.

For the laser initiation phase of the CKU-5C/A Alternate Propellant program, 1/4-inch cubes (0.25-x 0.25-x 0.25-inch) of each propellant composition were prepared. Following the established methodology, four power levels were established and 80 tests (20 at each power level) were conducted. The laser pulse duration was varied from test to test. Time to first light and the 50 percent "all-fire" threshold levels were determined. Functional tests on baseline propellant were conducted with this same test methodology to ensure viable comparisons could be offered. Again, by varying the pulse duration at each power level, an assessment of "sustained combustion" or "non-sustained combustion" was completed. The testing was conducted at ambient pressure with the 0.100-inch diameter laser beam being directed straight down on the propellant sample upper side. The laser initiation test results are conclusive to establish a "go" (sustained combustion) or a "no go" (unsustained combustion).

Over 800 individual tests were conducted as part of the laser initiation program. Ten differing propellant compositions were evaluated. All of the alternate propellant compositions tested exhibited higher 50 percent ignition threshold levels then the 50 percent threshold level for the baseline

The ACES II ejection seat has saved thousands of lives.

propellant. And, the 50 percent ignition threshold line for the baseline propellant lies very close to the time to first light line. Therefore, reducing the ignition energy should result in a reduction in the time to first light for the propellant and ultimately for the catapult itself. The propellant composition most closely exhibiting these characteristics was selected for full-scale catapult production. When the full-up CKU-5C/A rocket catapults were manufactured with this propellant composition, the subsequent testing confirmed the results of the laser initiation test program. Therefore, the laser initiation program was demonstrated to be an effective tool to determine the comparative differences between altering compositions without requiring a large number of full-scale tests of the final component.

The IHDIV Laser Initiation Team continues to improve the test methodology and data analysis processes. Continuing improvement is the key. The most evident step in this continuing improvement program is the introduction of a new CO_2 laser into the system. While the current laser continues to perform very well, the new DEOS-Coherent Model GEM-200PC is much smaller in size, easier to control, provides visible alignment checks, and can easily be configured with a digital data acquisition system. This improved CO_2 laser capability will allow IHDIV to continue to support the fleet with this technology until the Star Wars light sabers are available for everyday use.

The IHDIV Laser Initiation Team includes Tom Blachowski, Brent Morgan, Ed Tersine, Jay Dalton, John Constantine, and is ably assisted by Dr. Peter Ostrowski of Energetic Materials Technology.

Keeping the Tomahawk Cruise Missile & Trident Submarine Programs on Track

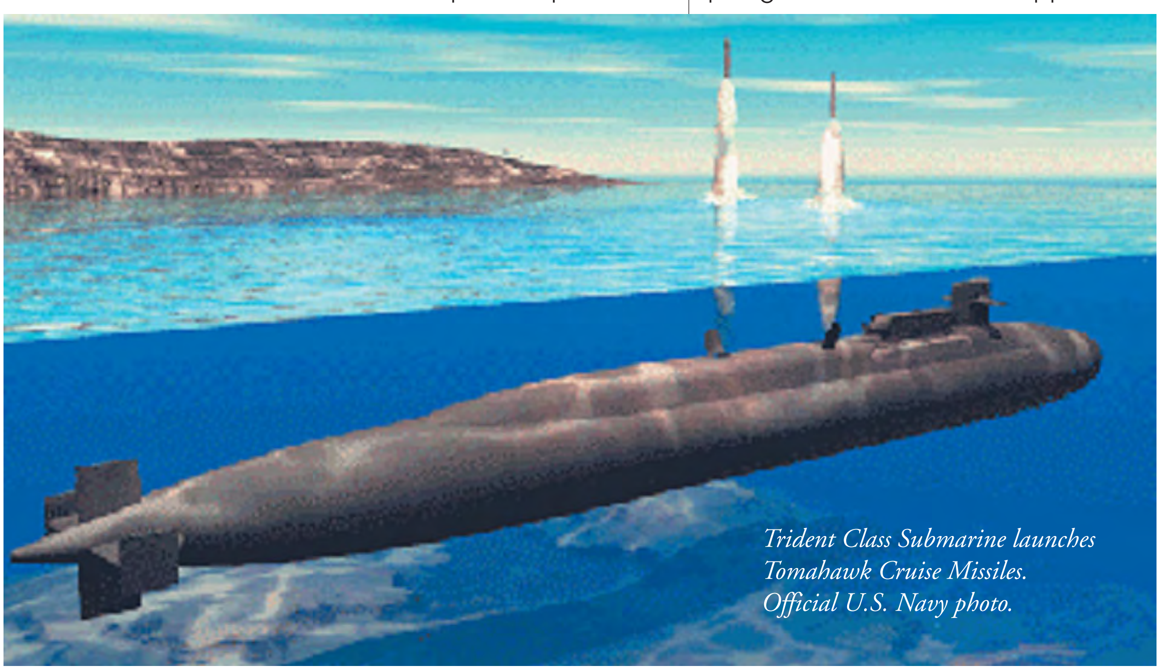
by James Clark & Dave Seroskie
Applied Technology Department
& Weapons Department

Before booster ignition, a Tomahawk cruise missile on board U.S. Navy submarines is propelled out of its launch capsule by a Mk 75 gas generator. The gas generator contains a solid propellant cast from POU-2 casting powder.

Intended to last the remainder of the Tomahawk program, the Indian Head Division, Naval Surface Warfare Center (IHDIV) manufactured a 7,300-lb lot of this critical casting powder in 1992. However, the Navy's heavy operational usage of Tomahawk missiles in the last seven years, coupled with manufacture of new missiles to replenish the inventory, and the conversion of four Trident submarines to become Tomahawk capable launch platforms, has rapidly depleted that "lifetime" supply.

Over a decade later, IHDIV was tasked to manufacture this crucial system component to meet the load out schedule for the first of the converted Trident submarines in early 2007. The Missile Branch of the Weapons Department Chemical and Extrusion Technology Division of the Applied Technology Department, Chemical and Mechanical Properties Division of the Energetics Evaluation Department, and the High-Energy Materials Division of the Research and Technology Department are all working together to fulfill this mission, which has been marked by many initial start-up and in-process challenges.

POU-2 casting powder is composed of a double base (ABL-917) and single base (HES-6745.1) casting powder, blended in a 60/40 parts by weight ratio, respectively. Last produced over a decade ago, some of the suppliers of the raw ingredients used in the casting powder no longer exist, requiring materials from new suppliers to be



Trident Class Submarine launches Tomahawk Cruise Missiles. Official U.S. Navy photo.

ABL 917 double base grains and strands (left) and HES 6745.1 single base grains (below).

tested to find acceptable replacements. Furthermore, some of the processing procedures were outdated and needed to be re-evaluated.

Finding itself without a source for the single base casting powder, IHDIV began development of this powder in early 2000, with process optimization conducted and achieved in 2003. A variety of small-scale mixes were made using various solvents and solvent ratios until the material processed successfully.

The double base casting powder also went through a series of small-scale mixes to determine the best solvent system to use. A tri-solvent system was finally chosen, as it produced material that was comparable to the original manufactured in the past.

In addition to finding acceptable ingredients for the casting powders, cutting is also an area of concern. The double base and single base grains are 0.035 and 0.040-inch right circular cylinders, respectively. Each "spaghetti" strand is hand fed into the cutters. To achieve accurate strand cutting and eliminate tails (excess material at the end of the grain resulting from poor cutting), the cutter blades have to be sharpened and adjusted to very precise tolerances. In addition to chemical properties, having accurate cuts and dimensions lead to better packing and ultimately affects the performance of the gas generator.

To ensure the casting powders would perform as well as they processed, the Chemical and Mechanical Properties Division analyzed both materials for physical and chemical properties to verify that they met their specifications. Some of the test methods called out in the specifications were outdated and no longer used in IHDIV facilities. Therefore, alternate methods were examined and validated as acceptable substitutes. Each production mix of both casting powders is sampled and tested to verify its conformance to the requirements.

Once the double base and single base casting powder lots are analyzed and meet specification, they are combined according to the specified ratio in a 5,000 lb blending barrel. After blending, the POU-2 casting powder is transferred to 1,000 lb hoppers. The hoppers are then remotely emptied into a large screening machine to separate the oversized and undersized materials from the powder. During screening, acceptable grains are discharged into fiber drums using an automated pack-out system. More samples are taken from the top, middle, and bottom of random drums to verify the casting powder is within the specified ratio (60/40) of double base to single base casting powder.

In May 2005, the first production lot of POU-2 casting powder (2,416 lb) was completed, reaching approximately half of the desired goal. The Chemical and Extrusion Technology Division continuously work to process one mix per week of single base powder and two mixes per week of double base powder, yielding 260 and 330 lb, respectively. The second lot of single base casting powder was completed in August, at which time the second lot of double base casting powder production began. In November, the double base powder will be completed, and the two powders will be blended together for delivery in December 2005.

The broad range of expertise in missile systems, chemical and extrusion technology, chemical and mechanical properties, and high energy materials found at IHDIV has allowed for the production of this mission critical component, enabling the Navy's Tomahawk and Trident Submarine programs to remain on schedule.

If you would like more information on this program, or IHDIV capabilities in this arena please contact Dave Seroskie, david.seroskie@navy.mil.

USS Florida launches a Tomahawk Cruise Missile during Giant Shadow in the waters off the coast of the Bahamas. Giant Shadow is a Naval Sea Systems Command (NAVSEA) Naval Submarine Forces experiment to test the capabilities of the Navy's future guided missile submarines. Florida is one of four Ohio-class ballistic missile submarines (SSBN) being converted to guided missile submarines (SSGN). Giant Shadow is the first experiment under the "Sea Trail" initiative of the Chief of Naval Operations' Sea Power 21 vision and the first in a series of experiments before converting and overhauling for four SSBNs to SSGNs. The SSGNs will have the capability to support and launch up to 154 Tomahawk missiles, a significant increase in capacity as compared to other platforms. IHDIV's expertise in casting powder will help keep this program on track for deployment. U.S. Navy photo.

Meeting the Needs of the Warfighter: Ensuring Sustainability of Energetic Systems

by Wesley Shaw
Energetics Evaluation Department

In order to sustain functionality, reliability, and safety, the Indian Head Division (IHDIV) must ensure systems meet or exceed these capabilities for their entire life cycle. The IHDIV mission includes management, design, and evaluation of energetic systems to meet the needs of the warfighter.

The Mechanical Properties Characterization Group has the expertise, facilities, and procedures to assess the material properties of energetic materials as well as a wide range of inert subsystems in support of IHDIV's diverse efforts.

Located on the lower end of the IHDIV peninsula, the Mechanical Properties Characterization Group includes the materials test team of Heather Kriebel, Wes Shaw, and Lori Weedon, along with Robert Rast as the technical lead for analysis and aging programs. The group has over 50 years combined experience in test and analysis of energetic materials including: composite propellants, double base, multi-base gun propellants, and many inert subsystems. Personnel provide lot acceptance data for current on station production materials in support of quality assurance (QA), as well as con-

Two F/A-18C Hornets fly over the Pacific Missile Range facility armed with SIDEWINDER missiles. Official U.S. Navy photo.

Wesley Shaw of the Energetics Evaluation Department testing cold lot acceptance samples.

ducting service life predictions for ongoing quality evaluation (QE) rocket motor and warhead programs.

Current generation test equipment enables the team to evaluate the material properties of propellants and explosives as well as many inert subsystems utilizing Chemical Propulsion Information Agency (CPIA) and American Society for Testing and Materials (ASTM) methodology. Test services provide engineers and analysts with material properties data for a wide variety of loading conditions. Test machines are capable of measuring hundredths of pounds up to a maximum of 20,000 lb under tension and compression at a useful range of temperatures. Using customized equipment, the group also conducts fatigue testing, high rate testing under pressure and temperature up to 5000 inches per minute, and ultra low rate testing down to 0.0001 inch per minute. Other specialized testing includes: bulk modulus vessel, volume dilatation, digital Shore A hardness, penetrometer profiles, creep compliance, and constant (or variable) stress and strain rate testing under temperature and pressure. Without this type of testing and analysis, we would be unable to fully characterize the behavior of energetic materials. Most energetics are said to be viscoelastic, which simply means that their mechanical behavior is dependent on both temperature and strain rate often requiring large test matrices for full characterization. Modeling and simulation efforts here at IHDIV depend on complete characterization to maintain accuracy in support of safe and effective units for the fleet.

Capabilities Enhanced by Digital Technology

One of our newest capabilities is a digital video extensometer for making ultra-accurate strain measurements. Strain measurement is the amount that a given material can deform under a given stress without failure. The addition of this new system allows for much improved mechanical properties of data, which in turn improves predictions, analysis, and interpretation of aging properties, which will have a critical impact on future QE efforts.

Traditionally, strain measurements on energetics are approximate since the concept of "effective gauge length" (EGL) is almost always used in accordance with CPIA Pub 21, Section 4.3.2.1. Mathematically, strain breaks down as the change in sample length divided by the original length;

IHDIV produces service life predictions for many systems such as the Tactical Tomahawk Cruise Missile shown. Official U.S. Navy photo.

however, there is much debate as to the value of this "effective original length" due to the nature of viscoelastic materials. For many inert material systems, this problem is avoided by the use of an extensometer, which isolates a small region of the gauge and reports dimensional changes in that region. In the case of energetics however, the use of contact extensometers is rare since: (a) they are time consuming, (b) they can cause premature failure of the test specimen, and (c) they introduce operator inconsistency as a test variable. As a result, most lot acceptance strain values are approximated from crosshead displacement and EGL.

How does it work? First, horizontal parallel lines are drawn on the gauge section of the sample using a template. After the sample is installed in the grips, the video system will acquire the original length as the distance between the lines. As the sample is strained, the distance between these lines is monitored by the video system, and actual strain of the isolated gauge length is calculated by the software and plotted versus the measured stress. These measured strain values give a more realistic representation of the material response over the traditional EGL values.

The stress, strain, and modulus information from the new hardware are used as inputs for Finite Element Analysis (FEA) simulations of the all-up rocket system. The FEA model can be two dimensional or three dimensional depending on geometry, but will always include structural components of the rocket motor including case, insulator, propellant grain, etc, and their respective properties. This complete system definition ensures that the correct three dimensional stress states are included in the analysis as well as any thermal stresses/strains which will be developed by differences in thermal expansion. The accuracy of the service life prediction is directly related to the accuracy of the measured strain values, as the model can only be as good as the input data.

Service Life and Aging Programs

Lot acceptance testing of materials is an important part of material qualification in terms of safety and performance, but determining the materials' integrity 20 to 30 years down the road can prove to be even more critical. It is imperative that units perform their intended mission with acceptable reliably, but it is also most critical that older units are safe to load and fire without risk of catastrophic failure in proximity of ship personnel. In addition to production support, the group performs and manages accelerated aging programs on energetic materials.

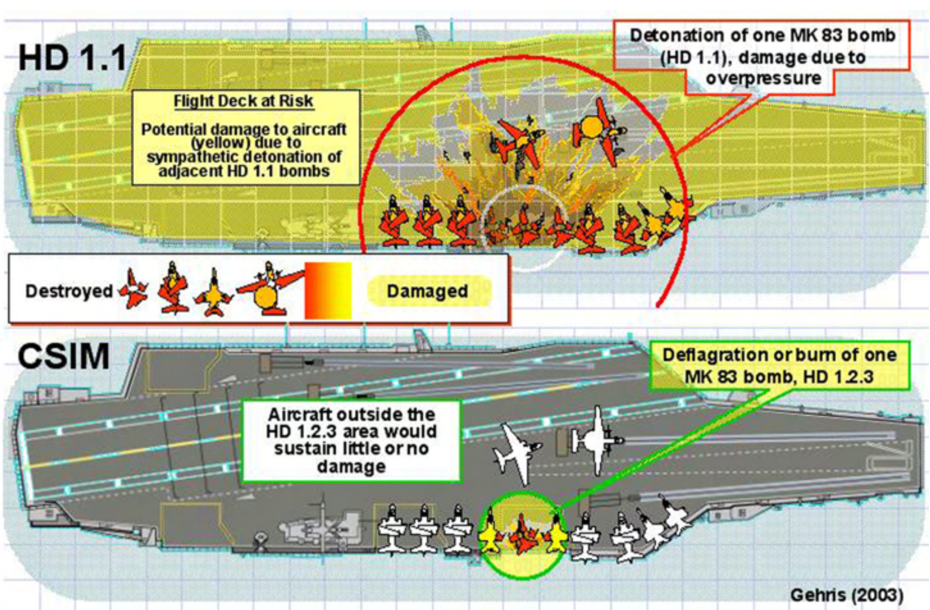
The service life process is a QE effort and typically involves a multi-year commitment but is invaluable to program managers in determining life cycle system integrity. First, a complete baseline characterization of the energetic material is performed, which includes chemical and physical properties characterization, followed by accelerated aging of the bulk material for at (least) three different elevated temperatures to accelerate the aging process. The aged material is periodically withdrawn to determine the new material properties. Energetic materials all "age" at different rates and for different reasons depending composition and environmental factors. Critical parameters from the material's changing characteristics are tracked using the proven Smith Failure Envelope method. The data is distilled using a patent pending technique for determining the kinetic aging rates of the energetic material.

The Arrhenius aging rates are used to predict future propellant properties. The baseline and predicted properties form the foundation for a finite element model (handled by IHDIV Weapons Department) of the specific unit to determine critical loading conditions and provide a prediction for end of service life. Often field units are returned for dissection and test as part of model validation support of on-going QE efforts.

Analysis of mechanical properties through appropriate stress criteria coupled with finite element analysis has produced service life predictions for many systems to date including: Vertical Launch Asroc (VLA), Standard Missile, SIDEWINDER, Tomahawk, High-Speed Antiradiation Missle (HARM) and the Mk 50 Torpedo warhead, with other programs in progress. The team provides accurate service life recommendations for Army, Navy, and Air Force units, providing vital insight regarding the future reliability and safety of energetic systems.

The mechanical properties characterization group of IHDIV's Energetics Evaluation Department continues to support the needs of the division and the Navy with the expertise, facilities, and procedures necessary to assess the material properties of energetic materials.

Please feel free to contact any member of the team (301.744.1684/4653/4242/4561) with questions regarding material selection, test capabilities, future aging programs, or supporting new test initiatives.



Correction from Summer 2005 Swoosh & Boom

This graphic shows the effect on the right deck of an HD 1.1 Mk 83 bomb detonation (top) versus an HD 1.2.3 Mk 83 bomb detonation. The CSIM deflagration has a much smaller arc of damage, thus enhancing survivability and warfighter capability.

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